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1. Introduction

Traditional environmental policies set out to reduce air pollution by direct regulation, mainly in the form of emission standards. An example is the EC large fuel combustion plants directive which prescribes for new combustion plants emission standards in terms of mg SO_2 per m^3 flue gas, depending on the size of the plant. This type of rule leaves the responsible manager little room with regard to how and by how much to reduce SO_2 emissions. More flexibility can be created by assigning emission quota. The larger the number of sources, plants or firms that is involved, the larger is the flexibility and the scope for cost savings in pollution control. One step further is to create markets for emission permits, with regular trade and price notations that signal the scarcity of the environment in its function as a sink for emissions.

In this paper we shall give a survey of efforts that have been made to relax the rigidity of the traditional system of direct regulation in Europe and the USA. The experience runs from simply adding quotas to the existing system of emission standards in Europe to the creation of full-fledged markets in the USA. The question then arises whether European countries can and should follow the US example or avoid such radical policies.[1]

Therefore the objectives of this paper are twofold:

1. to analyze how a selected number of schemes to increase flexibility in air pollution control are designed and operate in practice;
2. to evaluate their cost-effectiveness, environmental effectiveness (the extent to which environmental goals are met) and administrative practicability (information requirements and costs).

The paper is limited to applications for air pollution.

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[1] Overviews of the use of economic incentives, and marketable permits in particular, have been provided by Anderson et al. (1990), Carlin (1992), Elman et al. (1992), Hahn, (1989), Hahn and Hester (1989a, 1989b), Opschoor and Vos (1989), and Tietenberg (1990), among others. These overviews are biased since they mainly rely on the experience in the USA. They ignore recent steps in Europe as well as international applications. Moreover, they do not deal with the most recent and radical attempt to implement marketable permits: sulphur emission trading in the USA after the Clean Air Act Amendments of 1990. This paper attempts to bridge the gap.

The structure of the paper is as follows. Section 2 discusses European steps to increase flexibility, evaluating Danish (section 2.1), Dutch (2.2) and German experience (2.3) and giving an assessment in section 2.4. Section 3 concentrates on EPA's emission trading program in the USA, describing its rules and the experience in running the program in 3.1 and comparing it with European actions in 3.2. Next, in section 4, we describe the sulfur allowance trading scheme in the US acid rain program. Section 5 gives the conclusions.

2. Increasing flexibility in Europe

In Europe, authorities have made efforts to increase flexibility under the existing system of emission standards. This section surveys the solutions and experiences in three countries: Denmark, the Netherlands and Germany.

2.1 Power plant quota in Denmark

The quota arrangements

As in other European countries, reduction of SO_2 emissions in Denmark is realized mainly by setting emission standards for new sources. However, as early as 1984, Denmark accepted legislation that imposed a bubble of 125000 kton SO_2 on the emissions from its power plants, to be attained in 1995. In 1987 a ceiling for NO_x was set. On the basis of ongoing international negotiations the original ceilings have been lowered. As of June 1993, the SO_2 quota is 116000 kton for 1995 and 73000 kton for 2000. The NO_x quota for 1995 is 85000 kton and 61000 kton for the year 2000 (Elkraft, 1993). The objective of these quotas is to provide more flexibility to the power plants in meeting emission reductions (Sørensen, 1993).

The Ministry of Environment fixes the quotas each year for the coming eight years after a review of plans submitted by the power companies. Two power plants consortia are involved: Elsam and Elkraft. Quotas for the first four years are binding and quotas for the remaining four years are provisional. The quotas pertain to aggregated emissions of all plants with a capacity of 25 MWe or more. Although quotas are fixed on an annual basis, the annual ceilings may be exceeded maximally by 10% as long as the cumulative emission ceilings for the four-year period (1993-1996 and 1997-2000) are not exceeded (Elkraft, 1993).

The quotas are set on the basis of zero net import of electricity. If (net) import of electricity occurs, the national emission quota is reduced by the calculated quantity of emissions that would have occurred if the electricity now imported would have been produced in Denmark.

The allocation of the annual ceilings over both power plant companies is left to the two companies. They can rearrange emission reductions (Sørensen, 1993). However, flexibility is limited, since emission standards for new plants as laid down in the EC-directive on large combustion plants and in Danish regulations for NO_x have to be met (Sørensen, 1993). Finally, compliance is necessary with national ceilings that are set for amounts of emissions by existing large combustion plants under the same EC-directive.

Regarding monitoring and enforcement, the electricity companies have to submit reports containing information on past emission each year, on future development of emissions, as well as on the pollution control measures foreseen. Local authorities are responsible for monitoring and enforcing the actual emission levels.

Cost savings and environmental impacts

Estimates of the cost savings of the bubble concept are not available. Cost savings are expected since the power companies can shift to low sulfur fuels and to other fuels (natural gas, biomass) in addition to applying flue gas desulfurization and other technical measures (Sørensen, 1993). The power companies do seem to aim at meeting the emission quotas at minimum costs in order to keep electricity price as low as possible (Elkraft, 1993, p.B7; Ølsgaard, 1994).

At the same time, the structure of the Danish electricity industry is such that some doubts about efficiency remain. The shares of the formally private power companies are held (indirectly) by local communities, among them the city of Copenhagen, which might have other objectives than pure cost minimization. There is room to pursue such objectives, since the two consortia possess more or less monopoly positions in their region and the Danish energy law allows the inclusion all costs in the electricity price (Ølsgaard, 1994). This suggests the existence of a so-called 'soft budget constraint'. This means that the strict relationship between expenditure and earnings of an economic unit is relaxed since extra expenditures can be covered by extra support (Kornai, 1986).

Regarding environmental effectiveness, available data suggests that actual emissions for 1992 for both sulfur and nitrogen oxides were around 10 percent below the allowed quotas. In previous years emissions were also below the quotas and they are expected to remain lower than the quota in the future (Elsam/Elkraft, 1993). Power companies regard it as one of their goals to ensure that the quotas are met, if only because they want to avoid negative publicity. This, combined with uncertainties inherent in planning electricity production, implies that actual emissions might turn out to be lower than the quotas (Ølsgaard, 1994).

Little is known about the administrative practicality of the Danish quota system and its impact on innovation. The quota system might be less practical than emission standards due to the additional meetings between the environmental Ministry and the power companies (Sørensen, 1993).

2.2 Sector covenants and bubbles in the Netherlands

The covenant with the electricity producers

In the Netherlands, the authorities responsible for reduction of SO_2 emissions are the national government and the governments of the provinces. The traditional policy has been to set national emission standards, taking into account the EC-emission norms. As an innovation in policy, the national government of the Netherlands and the twelve provinces signed a covenant on the reduction of sulfur- and nitrogen oxides emissions with the union of electricity producers (SEP) and the four individual electricity producers in 1990. The covenant is an agreement between the parties in which the united electricity producers commit themselves to reduce acidifying pollution more than was asked by existing standards (SEP, 1991) up to the year 2000. The motive for the ceilings is that they offer the electricity producers possibilities to reduce emissions in a more cost-effective way than would be possible by requiring uniform emission standards for classes of installations (SEP, 1991).

The objective of the covenant is to reduce SO_2 emissions of power plants to 18 kiloton and NO_x emissions down to 30 kiloton in the year 2000. The ceilings are not completely fixed but leave some elasticity.[2] Electricity producers are public utilities, very much as in Denmark, and are owned by the provincial authorities. Although there are four electricity producers, decisions on fuel use and the utilization of the means of production are taken by the SEP. Producers participate in a system of cost-sharing that compensates producers who have to use relatively expensive fuels and equipment. In this sense the bubble implies intra-firm rather than interfirm trading.

Regarding monitoring and enforcement, the SEP has to produce a plan that spells out the measures to reduce emissions to the level set in the covenant every two years. The plan has to be approved by an expert commission in which the Ministry of the Environment, the SEP and the provinces are represented. The individual producers have to report to the provinces and the SEP. The provinces agree to implement the covenant but can defer from this if that is necessary to meet air quality standards other than standards for the reduction of acidification. Parties can alter the covenant if unexpected environmental changes occur. The ceilings can be altered if electricity demand or import depart substantially from what was planned. The parties can also have the covenant dissolved if they cannot agree on the emission reduction plans or if the ceilings cannot be met by all reasonable means (SEP, 1991).

Is the covenant cost effective?

In implementing the bubble the SEP has to observe certain limitations:

1. existing power plants have to meet the existing emission standards;
2. relatively new plants have to meet more stringent standards, laid down in the covenant.

Despite these limitations, electricity producers expect that the covenant saves them 500 million guilders compared to an alternative policy of setting stricter uniform emission standards to meet the same ceilings. This would have raised costs to 1 billion guilders. The

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2 The SEP can increase the NO_x cap by 5 million kg if the SEP supplies also heat on the basis of 1250 MWe. If the actual heat supply is less, the allowed increase is reduced proportionally. The sulphur cap can be increased by 4 million kg if flue gas desulphurization units are out of operation due to technical problems but operate within the applicable legal framework. These corrected ceilings can be exceeded once every three years by 3 million kg maximally.

cost savings are achieved by applying more expensive pollution control equipment that reduces emissions below the required emission standards on those combustion installations that have a longer remaining lifetime, have more operating hours per year, or have to be upgraded anyway (Lubbers, 1993).

Regarding the environmental effectiveness, the covenant states that in order to reduce acidification it is especially important to reduce the total volume of emissions in the Netherlands (SEP, 1991). This raises the question whether the covenant can indeed meet the total emission ceiling. On the one hand, the covenant offers several possibilities to bust the caps (such as heat supply, other electricity forecasts, non-operating flue gas scrubbers) and the SEP eventually can back out of the agreement that raises some doubts. On the other hand, the government can threaten with the (more expensive) alternative: setting more stringent uniform emission standards in new legislation as well as also lowering the caps in case of unexpected environmental changes.

Bubble and averaging for refineries

Existing policies for oil refineries do allow some flexibility: instead of a standard for each single source, an average standard was set of 1000 mg SO_2/m^3 flue gas for the sum of fuel-related or process emissions for groups of plants per refinery. This implies that some combustion plants within a single refinery may overcomply and others may undercomply, as long as the average standard is met. This regulation has been complemented by an agreement between the Ministry of the Environment and the five companies engaged in oil refining. Parties agreed on a ceiling of 36 kiloton SO_2 emissions for the oil refinery sector as a whole from the year 2000 onwards. The 36 kiloton bubble corresponds with a 1000 mg SO_2/m^3 standard at the 1980 level of oil input. Therefore, the 36 kiloton emission ceiling can be seen as an instrument to prevent growth of emissions arising from increasing oil input. The distribution of the maximally 36 kton of emissions is left to the five companies that together own six refineries. Each single refinery still has to meet the average emission standard of 1000 mg SO_2/m^3 flue gas. Moreover, this average emission standard will be lowered to 500 mg in the near future (Dekkers, 1993).

Cost savings and environmental impacts of refinery bubbles

Estimates of the cost savings of the bubble and of setting an average standard are not available. The largest flexibility is probably not reached by the cap but by the average emission standard. The cost savings are refinery-specific; some refineries have 30 plants within a refinery, others only two (Dekkers, 1993). Gaasbeek (1993) doubts whether the average standards give so much flexibility, since refineries have fewer installations than the electricity producers. Some companies have installed (catalytic and thermal) crackers, such as Esso's flexicoker, primarily for economic reasons: cracking increases the share of light oil fractions which have higher market values. As a byproduct, sulfur emissions have decreased considerably: down to 350 mg SO_2/m^3 in refineries that have installed such crackers. Actual (1993) SO_2 emissions were around 60 kiloton despite a formidable increase in oil input. This implies that there is no additional constraint for refineries that meet the average 1000 mg/m^3 standard. One would expect no trade between refineries under such conditions and, in practice, inter-refinery trading seems not to have occurred. Therefore, the potential obstacle to trade arising from the fact that no distribution of emission permits to individual refineries had taken place was not an actual bottleneck.

If the emission standard would be lowered to 500 mg SO_2/m^3 on average per refinery, given the same fuel input and quality as in 1993, maximal total emissions would be 22.5 kton. This suggests that the new, average emission standard per refinery would be the binding constraint and not the cap of 36 kton on total emissions of all refineries taken together. Consequently, the cap would not give any incentive for interfirm trading of emission permits, since every single refinery has to meet the average standard. The new standard would reduce the demand for emission reductions from other firms to zero, not allowing any cost savings other than intra-firm 'trading'.

The environmental effects of the bubble are not straightforward. Given the increased fuel input compared to that in 1980, the cap does, in principle, prevent the increase in emissions above their 1980 level, and, in effect, lower the effective average emission standard from 1000 to 800 mg/m^3. However, the installation of crackers, driven by economic motives, reduced actual emissions below the ceiling of 36 kton SO_2.

Monitoring does not seem to have solved any problem, since total emissions can easily be calculated on the basis of fuel input, sulfur content and information about the applied abatement technology. Adding process emissions, and accounting for catalytic crackers gives total emissions (Dekkers, 1993).

The administrative practicability of the average emission standard and bubble are believed to be high. One single standard for each refinery requires less administration than separate standards for every single installation, as is the case in Germany. The concept of an average standard also fitted better into the existing regulatory framework that in the past prescribed average sulfur content of 2% S (3400 SO_2/m^3) in the fuel cocktail of each refinery (Dekkers, 1993).

2.3 Offsets in Germany

Plant renewal clause and compensation rule

In Germany the transfer of emission reduction obligations from one unit or firm to another is possible as a means to control air pollution. Two rules apply: the plant renewal clause and the compensation rule.

The plant renewal clause pertains to the construction of new plants in areas where air quality standards are exceeded. In principle, the Federal Immission Protection Law ("Bundes-immissionsschutzgesetz") and the Technical Guidelines for Air Pollution Control rule out construction of new plants in non-attainment areas - which are areas where the air quality standards are exceeded - even if the firm meets the state-of-the-art emission standards. The plant renewal clause in the 1974 technical guidelines, however, does allow the location of a new plant in such a non-attainment area if the new plant replaces an existing plant of the same kind. These plants do not have to belong to the same firm but have to be located in the same area. In 1983 the guideline was extended; not only the closing down of an existing plant but also its renovation could be used to offset the additional emissions of a new plant. The offsets, however, would have to lead to a reduction in the annual average concentration in the area and the new plant has to meet the state-of-the-art emission standards (Sprenger, 1989; Opschoor and Vos, 1989).

The compensation rule was included in the 1986 revision of the technical guidelines. As part of the revision, existing installations had to be modernized to meet the stricter emission standards, usually within five years. The core of the compensation rule is that the cleanup period can be extended to eight years if emission reduction measures taken at existing installations (from the firm or other firms) would provide more emission reductions than would otherwise result from application of the technical guidelines for each individual plant. This compensation can only be used by installations within the same geographical area of impact and for the same pollutants or pollutants with comparable impacts (Schärer, 1993).

Cost-efficiency and environmental effectiveness

The cost saving derived from the plant renewal clause is limited since it can be applied only in the few areas where air quality standards are exceeded. It is peculiar that the rules of the clause further restrict its cost-efficiency. The clause can only be used if the additional environmental stress from the plant is limited to 1 percent, if the additional emissions are fully offset by plants in the same area and if the new plant starts operating after the closing down of the old plant. Moreover, the clause does not apply to the location of new plants in attainment areas even if this would not lead to exceeding air quality standards (Sprenger, 1989).

The contribution of the compensation rule to cost savings is also small. In only 50 out of 17000 clean-up cases was the rule used (Schärer, 1993). The most important reasons for its restricted use are (Schärer, 1993; Sprenger, 1989):

- the short time limit for approval of plant renewal proposals (one year);
- the stringent emission reduction requirements at existing installations;
- the necessity of multiple trades since most new firms emit more than one pollutant in the air;
- the small size of the areas in which offsets are allowed.

The environmental impact of both the renewal clause and compensation rule is neutral to positive. The renewal clause prevents increases in emissions in non-attainment areas. The compensation rule can only be used if total emissions are reduced further (Sprenger, 1989).

On the administrative requirements, no data was available. Sprenger (1989) believes that the plant renewal clause stimulates innovation but does not supply empirical evidence.

2.4 Evaluation of European experience

The European experiences with giving polluters more flexibility in making their own choices have mainly taken the form of bubbles and compensation schemes that allow increase of emissions at a source as a compensation for decreases elsewhere. The schemes have the common property that the increased flexibility has been used almost exclusively for internal compensation. We have found no evidence for 'external' trade where permission to emit was transferred from one party to the other in exchange for money. This also implies that a market for emissions could not develop.

The absence of markets and the preponderance of internal solutions is explained by several factors. It is partly explained by the structure of the industry, such as the electricity producers in the Netherlands, who are organized as a legal cartel, as well as the high degree of concentration in the Danish electricity industry. A second reason, valid for the oil refinery sector in the Netherlands, was the absence of real scarcity, which would have given rise to external trade in emission permits at a positive price, and the fact that emission quotas were not allocated to individual firms but to the sector as a whole. A third reason is that flexibility, which has been given with one hand, has been taken away with the other hand by maintaining existing direct regulation and even by adding additional requirements (such as the case of the 1983 revision of the plant renewal clause in Germany). It should be noted that these last features also limit the opportunities for internal compensation and for improving cost effectiveness.

It is striking that the bubbles have been granted to homogeneous sectors. There is a plausible interpretation for this. Authorities were willing to reduce their own direct grips on emissions at the firm level only in those cases where they could negotiate with the group and make it responsible for keeping emissions below the ceiling. If the group can be held responsible for (good) performance, it is not really necessary to delineate an exact level of initial emissions to which the single polluter is entitled. The absence of a clear statement of baseline emissions for individual firms is indeed one of the features of the European bubbles.

Certainty on group performance would be difficult to achieve if the group was heterogeneous and the number of polluters involved was large. At the same time, if parties are heterogeneous and large in numbers, the opportunities for external trades and the development of a formal market for emissions would increase. But then clear contracts and enforcement by the authorities require an initial distribution of emission allowances among polluters.

This contrast between the demands of a market for emission permits, on the one hand, (heterogeneous polluters, large numbers, delineation of entitlements) and actual policies on the other hand (homogeneous polluters, small numbers, no delineation of entitlements), supports the conclusion that the European arrangements for increasing flexibility discussed in this paragraph were never intended as a basis for the development of a market for emission permits. Much more, the bubbles had the nature of a direct regulation for the group as a complement to the direct regulations for each single polluter within the group.

3. EPA's emission trading policy

3.1 Design

The basic statute governing air quality in the USA is the Clean Air Act. The Act is directed at the implementation of emission control strategies to meet national ambient air quality standards (NAAQS). These standards specify maximum allowable concentrations for specific pollutants in the air (Liroff, 1986; USEPA, 1990). Ambient standards exist for CO, NO_x, lead, particulates, ozone and SO_2 and are set by EPA (the Environmental Protection Agency). For non-attainment areas, where one or more of the standards are violated, individual states have to develop state implementation plans (SIP) showing which measures will be taken to meet the standards. For attainment areas, where air quality is better than the ambient standard, prevention of significant deterioration standards (PSD) specify the allowable increments in concentrations. Moreover, technology-based emission standards (new source performance standards (NSPS)) were introduced in 1971 for both new and modified sources. These are, in order of stringency: lowest achievable emission reduction (LAER), best available control technology, accounting for economic considerations (BACT), reasonable available control technology, accounting for technological and economic feasibility (RACT). For non-attainment areas, new and modified sources have to comply with the most stringent standards: LAER. In these areas, existing sources have to apply RACT. In attainment areas, new and modified sources have to apply BACT (Liroff, 1986).

The development of emission trading began in 1972. In response to the formulation of NSPS, smelter operators proposed to avoid these standards if the additional emissions of new or modified sources could be netted out by other, cheaper measures at the same plant. (This was officially allowed in 1975 but a court decision in 1978 struck down this rule.) Nowadays, netting is allowed only insofar as the new or modified sources meet the applicable emission standards and if applicable emission standards are met by the plant.

Meanwhile it became clear that states could not meet their SIP deadlines and the offset policy was born. This policy allowed new and modified sources to enter non-attainment areas as long as they applied LAER technologies and any additional emissions would be offset by other existing sources in the same area; not necessarily within the same plant or firm. In practice, an 'overcompensation' of 10 to 20 percent has often been demanded. (This looks very much like the German plant renewal clause of 1974 discussed in section 2.) In attainment areas offsets are only allowed if the PSD standards are met.

In 1979, banking of emission reductions was allowed and the bubble concept was introduced. Banking allows firms to store permitted emissions that have not been used for later use. The bubble allowed emission trading between existing sources in attainment areas (Liroff, 1986). Within the bubble some sources are allowed to emit more than the BACT emission standard, on the condition that other sources compensate by reducing emissions more than the BACT standard demands. Both internal and external bubbles exist. In 1982, the bubble concept was revised, and interim, generic trading rules were formulated and the bubble was extended to non-attainment areas (USEPA, 1982). In 1986, EPA published its final emission trading policy statement, setting out general principles for emission trading (USEPA, 1986; Borowsky and Ellis, 1987).

The objectives of the emission trading policy are to stimulate more economically efficient means of control and to promote flexibility in order to meet air quality standards more quickly (USEPA, 1979, 1982, 1986). The pollutants covered are all air pollutants for which national ambient air quality standards exist, as well as hazardous pollutants.

A tradeable permit, or emission reduction credit (ERC), is defined as an emission reduction that is surplus, enforceable, quantifiable and permanent. Surplus means a reduction not currently required by law. This might pertain to an emission reduction below:

* the baseline emissions required for attaining and maintaining NAAQS;
* the applicable emission standards for new and modified sources.

A number of emission reductions are not eligible for use in emission trading such as reductions resulting from plant shutdowns. All existing sources and major new stationary sources in both attainment and non-attainment areas can trade (Borowsky and Ellis, 1987).

The initial distribution of permits is based on grandfathering. It depends on the definition of baseline emissions which are typically determined on a case-by-case basis. For attainment areas, the baseline emissions generally are the lower of the actual or allowed emissions of the firm. For non-attainment areas with approved SIP plans, baseline emissions are the emissions used in the SIP. For similar areas without approved SIP, baseline emissions should be the lowest of either actual or SIP allowable or RACT allowable for each of the three baseline factors for each source involved in the trade.

The options to increase flexibility (netting, offsets, bubbles and banking) cannot always be used to avoid emission standards and are not always mandatory (Hahn and Hester, 1989b, p. 370). In both non-attainment and attainment areas, new sources cannot use offsets to avoid emission standards (LAER/BACT). In these areas, modified sources, however, can use netting, and existing sources can use bubbles to avoid these standards. Only offsets are mandatory for both new and modified sources in non-attainment areas. Netting and bubbles, as well as offsets in attainment areas, are only optional and not mandatory.

The final generic rules governing trading as formulated in 1986 are manifold:

* Trades must be for the same pollutant;
* For particulates, SO_2, CO and lead trades must satisfy ambient tests. For VOC and NO_x no such test is required. An ambient test is a demonstration made to show that the trade has no significant impact on air quality. Trading is not allowed to violate NAAQS or PSD increments in attainment areas and cannot create new violations or delay in meeting NAAQS in non-attainment areas. Generally, this requires air quality modelling, unless the emission increases are below certain minimum levels or sources are located within 250 meters distance and certain conditions are met;
* Interstate trading is allowed as long as the requirements of the more stringent state are met;
* Emission credits from existing sources cannot be used to avoid NSPS for new sources, that is BACT in PSD areas or LAER in non-attainment areas;
* Bubbles are allowed in non-attainment areas as long as: baseline emissions reflect the lowest of actual SIP allowable or RACT allowable emissions, there is a net air quality

benefit (at least 20 per cent cutback in emission below baseline levels), ambient tests are satisfied.)

Finally, states may adopt alternative, generic trading rules that assure attainment and maintenance of NAAQS. Such state rules are not permitted to allow increase of emissions above the baseline. States have interpreted these rules to guarantee the NAAQS in three ways: requesting offset rates exceeding unity to ensure that emissions are reduced, limiting trading to relatively small zones to avoid hot spots, or requiring dispersion modelling (Hahn, 1986).

3.2 Cost-effectiveness

There is no dispute that EPA's emission trading policy resulted in considerable cost savings although it is also evident that the number of transactions that took place was lower than expected. Table 1 gives an overview of the 'traded' volumes and the estimated cost savings of the four systems (Hahn and Hester, 1989a; Dudek and Palmisano, 1988). Table 1 shows that the total expected cost savings range from 1 to 13 billion $. Annual cost savings are somewhere between 100 to 1400 million $. This is, maximally, 4 per cent of total air pollution control expenditures since 1975 (Anderson et al., 1990).

Netting can be regarded as the most successful part of the scheme. The large range in estimated trades reflects the lack of data. Cost savings of netting consist of savings in pollution control costs and savings in costs of permitting procedures. The average control costs savings are estimated at 0.1 to 1 million $ per case. Firms also save permit costs since netting avoids the use of permitting procedures for major sources. These permit costs savings range between 5000 and 25000 $ per case (Hahn and Hester, 1989a). Of the 2000 to 2500 offsets that took place 90 per cent were intra-firm. Palmisano and Dudek (1988) estimated a cost saving of $10000 per offset. By mid 1986, around 130 bubbles had been approved and around 100 were pending. Only 2 of these were interfirm. The estimated cost savings of the 130 bubbles range from 435 to 570 million $. The lower value uses lower average cost savings for state approved trades (less bureaucracy) and the higher value uses EPA estimates of an average cost saving of $3 million per bubble (Hahn and Hester, 1989a). The cost savings of banking are not available but are believed to be small in view of the small number

Table 1. Trades and cost savings under EPA's policy

Type	Volume (nr of trades)	Cost savings (million US$)	Period	Annual cost savings (million US$)
Netting	5000-12000	525-12300	1974-1984	53-1230
Offsets	2000-2500	20-25	1977-1986	2.5-6
- internal	(800-2250)			
- external	(200-250)			
Bubbles	132	435-570	1979-1986	60-80
- EPA	(42)	(300)		
- States	(90)	(135-270)		
Banking	< 120	small	1979-1986	
Sum		980-13135		116-1435

of trades. Remarkably, most of the costs savings have been realized by intra-firm netting or bubbles.

Various explanations have been offered for the relative paucity of EPA's emission trading. The major circumstances can be grouped in:

* regulatory restrictions on trade;
* uncertainty on status of property rights;
* high transaction costs.

Regulatory restrictions on trades were manifold. The demand for permits was limited since trading was crafted onto an existing regulatory framework (Boland, 1989). New sources still had to meet tight emission standards, restricting their demand. In attainment areas most new sources could avoid the obligatory use of offsets by applying BACT (Palmisano, 1993). Demand from existing sources is also limited, since they have either already installed (durable) pollution control equipment (Hahn and Hester, 1989a, Tietenberg, 1989) or because there is no effective (mandatory) policy for them to become engaged in trading (Rehbinder and Sprenger, 1985). Furthermore, the tougher definition of baseline emissions and the 20 percent additional cutback under the 1986 policy, shrank even further an already low interest in bubbles (Elman, 1993). Similarly, offset rates exceeding unity for distant sources restrict demand further (Dwyer, 1992).

Uncertainty on the status of the property rights also has limited trading. Uncertainty on whether sellers would achieve their reductions, on the buyer's baseline and whether the trade would be accepted limited the interest in trading (Hahn and Hester, 1989a). Moreover, trading policy, which sets the 'rules of the game' for firms that trade, was uncertain; it changed frequently and inhibited trading (Boland, 1989). There was too much debate and controversy making states afraid to touch the issue (Elman, 1993). The conflicting interests of environmentalists and business led to the creation of policies with no explicit definition of the nature of the property right (Hahn, 1989). Furthermore, for strategic reasons, firms would rather hoard permits for own, future use than sell them (Vivian and Hall, 1981). Responsible managers are believed to be risk-averse rather than act as textbook profit maximizers (Palmisano, 1993).

Transaction costs mainly consist of two elements: finding a trading partner and obtaining approval from the authorities. Searching for sellers is a formidable task, since market information is scarce, typical permit prices and clear price signals are absent, and the outcome of the search is unpredictable (Vivian and Hall, 1981; Hahn and Hester, 1989a; Foster and Hahn (1993). Brokerage fees depend on the value of the trade, the complexity of the transaction and vary between 4 to 30 % (Dwyer, 1992; Foster and Hahn, 1993). Another element are the costs and the length of the approval procedure. The administrative fees and the preparation of supporting material might, typically, cost $25000, with $10000 as a minimum (Foster and Hahn, 1993). Federal approval is much more costly and lengthy than state approval for emission trading (Hahn and Hester, 1989a). Air quality modelling is expensive and tends to raise new questions, and only a few trades requiring such models have been implemented (Tietenberg, 1989). Approval is not only costly but, and perhaps more important, its outcome is uncertain. Data for California suggest that, on average, out of the 100 trades proposed, 50 fall through during brokering; authorities accept 10 immediately, reject 20, and 20 have to be revised before being accepted (Foster and Hahn, 1993).

3.3 Environmental effectiveness, administrative practicality and innovation

EPA's emission trading program, generally, had a neutral impact on both the level of emissions and on air quality. In some cases bubbles lead to speeding up compliance and faster achievement of emission reductions. In other cases, partial deterioration in air quality may not have been prevented. Dudek and Palmisano (1988) maintain that emission trading has not been hostile to air quality objectives, since institutional safeguards exist for maintaining environmental protection. Although offsets, per definition, should reduce emissions, Hahn and Hester (1989a) remark that they may not protect air quality in the way intended because of inadequate emission inventories and the fact that allowable emissions may be higher than actual emission. Since the number of offsets was small, regulators carefully analyzed trades and trading rules contain provisions preventing emission increases the ultimate impact of offsets was insignificant. Bubbles and netting had little impact on emissions and air quality due to: the review process, the participation of environmental and public interests groups disapproving bubbles and the fact that netting is intra-firm and at the same location (Hahn and Hester, 1989a; Liroff, 1986). Banking has had a neutral to positive impact since banked permits could not or only temporarily be used (Rehbinder and Sprenger, 1985). In conclusion, emission trading, generally has had a neutral impact on emissions and air quality, although in some specific cases positive or negative impacts may have occurred.

The administrative burden of the emission trading policy can be viewed as high. Long preparation time of trading policies, frequent policy amendments, the lengthy approval process for individual cases (4 to 29 months), including the creation of an emission reduction credit, imply not only a substantial workload but also high administrative costs (Opschoor and Vos, 1989). In the case of netting, however, savings in administrative costs may have occurred since this allowed sources to avoid the major source review process (Hahn and Hester, 1989a).

The emission trading program is believed to have encouraged technological progress in pollution control to a limited degree. The availability of relatively inexpensive emission control opportunities combined with the lagged industrial response to the emission trading program in general, prevented broad scale invention and innovation (Dudek and Palmisano, 1988). In some cases, bubbles allowed industries to benefit from inventive solutions (Opschoor and Vos, 1989). The substitution of water-based solvents for solvents containing volatile organic compounds is one example (Tietenberg, 1991).

3.4 Concluding remarks

If we compare the European and the earlier US EPA effort to increase the flexibility of emission policies we see similarities as well as differences.

In the first place, there are resemblances in the instruments that have been used. EPA's netting policy for intra-plant compensations look very much like the Dutch average standard policy for oil refineries. The bubble policy in the US resembles the Danish and Dutch bubble for the electricity sector and the Dutch bubble for oil refineries. The offset policy seems not to differ very much from the German new plant clause and compensation rule. Only banking of emission reduction is lacking in Europe.

Next to these resemblances in the types of instruments that have been applied there are other similarities. On both sides of the Atlantic the rules that should increase flexibility have been crafted on an existing system of direct regulation in the form of emission standards. The new 'rules' have been more of a complement to than a substitute for existing emission policies. And in Europe and the US the 'trades' that have resulted from these added options have been mainly internal.

However, these resemblances should not distract our attention from the differences between both approaches. A first and important difference is that in the US the rules for increasing flexibility are more universal, explicit and formal. All four instruments - netting, offsets, bubbles and banking - are applicable in all states, apply (in principle) to all (stationary) sources under the Clean Air Act and the options and trading rules have been laid down in statutes. In contrast, the Dutch and Danish bubbles and the Dutch netting policy have, to a great extent, the character of informal, ad hoc solutions for homogeneous sectors with a very limited number of polluters. The German new source renewal clause and compensation rule is formal law and general but spatial and regulatory constraints restrict the number of feasible options considerably. As a result there have hardly been external trades in the three European countries, whereas they did occur in the US.

Although the EPA trading program was more conducive to creating markets than the European efforts to increase flexibility, it was far from perfect. In its design and even more in its actual implementation, it contained several elements that reduced the options for profitable trade between sources and higher cost effectiveness. The most important among them are the following:

- Part of the emission reduction credits can be confiscated by authority's demand that the compensating reduction of emissions exceeds the increase of emissions (offset rates > 1).
- Restriction of trade to relatively small areas.
- Continuation of existing emission standards.
- Uncertainty about how much of the potential seller's emission reduction will be authorized as ERCs and about how much of the potential buyer's increase of emissions will constitute authorized demand for ERCs.

The reduction of profitable trades brought about by these restrictions and uncertainties increases the problems of finding a trading partner. As a consequence, transaction costs increase, the market becomes more illiquid, price signals are sparse and unstable, which in turn increases market uncertainty. In the next section we shall see that EPA has learned from its earlier experiences and has managed to avoid the bottlenecks in its acid rain program.

4. Sulfur trading under the 1990 CAAA

4.1 Harnessing market forces to curb acidifying emissions

In November 1990, the Clean Air Act Amendments (CAAA) became law (US Congress, 1990; USEPA, 1990). Title IV of the amendments contains provisions to control the acid deposition caused by sulfur and nitrogen oxides emissions. The objectives of the acid rain program are (USEPA, 1992a):

1. to reduce the adverse impacts of acid deposition through a very drastic reduction in the annual sulfur dioxide (SO_2) emissions and of nitrogen oxides;
2. to achieve these reductions at the lowest costs by employing traditional methods and an emission allowance trading system.

For SO_2, the acid rain program introduces a nationwide emission trading scheme for electricity producers. This sector is responsible for nearly 70 percent of the SO_2 emissions in the US. The SO_2 emissions have to be reduced from 19 million tons in 1980 to about 9 million tons in 2000; a reduction of more than 50 percent. The 10 million cutback of emissions from fossil fuel fired power plants is to be achieved in two stages. Phase I starts in 1995 and affects 110 electric utility plants in 21 eastern and midwestern states, and places a cap of 5.7 million ton on these units. Phase II begins in 2000, tightens the emission caps for these 110 plants and imposes restrictions on smaller, cleaner plants throughout the US. In effect, a cap of 8.95 million ton SO_2 is placed on the number of allowances. An SO_2 emission allowance is an authorization to emit one ton of SO_2 during or after a specific year (USEPA, 1992b).

An allowance does not constitute a property right and does not limit the authority of the United States to terminate or limit such authorization (US Congress, 1990, p. 2591-2592). The initial allocation of allowances is such that allowances are allocated for each year beginning in 1995. The baseline for allocating allowances is the average fossil fuel consumption from 1985 to 1987. Additional allowances have been given to various units, including units in Illinois, Indiana and Ohio.

At the end of each year each unit is to hold allowances at least equal to its annual emissions. Furthermore, regardless of the allowances a unit holds it is never entitled to exceed the ambient air quality standards for public health (NAAQS). The unit is free to possess the allowances but it might not be able to use them to increase emissions if this threatens to violate ambient standards. The system for monitoring and enforcement is an interesting element of the scheme. Every source with a capacity of over 25 MW that falls under the programma has to install a continuous monitoring system (CMES). This implies that emissions are measured and recorded continuously. Compliance is determined at the end of the year. Units are granted a 30-day grace period during which allowances may be purchased to cover emissions. Excess allowances may be banked or sold. If a unit emits more allowances than it holds, a penalty of $2000 must be paid per excess ton of emissions. Moreover, the excess emissions have to be offset in the following year (USEPA, 1992a). The sanction applies 'automatically', without the necessity for EPA to bring the offender to court.

There are different ways to obtain permits, apart from the initial allocation. Firstly, allowances may be sold, bought or banked by any person, not only utility representatives, but also individual corporations, brokers, municipalities, environmental groups and private citizens. It was expected that a secondary market would develop when allowances that had been handed out are exchanged. Secondly, allowances can be obtained from three EPA reserves (USEPA, 1992b, 1992c):

1. for installing technologies that remove at least 90 percent of the emissions (phase I);
2. for implementing energy conservation or renewable energy projects;

3. a set-aside of allowances for auctions and for direct sales.

Newcomers (those who begin operating in 1996 or later) are not allocated any allowances for free. They will have to buy on the secondary market or from EPA auctions and direct sales. However, independent power producers have priority in purchasing allowances for a fixed price of \$1500 (indexed to inflation) in the direct sales (USEPA, 1992c).

The purpose of the auctions and annual direct sales is to ensure that independent power producers (IPP), which were not covered by the grandfathering scheme because of the small size of their capacities, but are the fastest growers in the sector, will get the allowances they need. But other parties are admitted as well as buyers or sellers. These allowances come from a special reserve of 2.8 per cent of the annual allowances.

The auctions are held once every year, and began in 1993. Auctions and direct sales have been made a part of the trading scheme for fear that potential entrants (independent power producers) would be unable to obtain a sufficient number of emission allowances in the secondary market. The auction consists of a spot auction, where allowances are sold that can be used in the same year (from 1995 on) and an advance auction of allowances that can be used not earlier than seven years after the year they have been emitted. In the auction, a fixed number of permits is offered from the EPA reserve. In addition to the EPA supply is the supply of other holders of allowances who are willing to sell. They state the number and type of allowances on sale and, optionally, their reservation price. Bidders have to send in sealed orders on the number and type of allowances they are willing to buy at a stated (maximum) price. The auctioneer then couples the highest demand price with the lowest supply price until the point where demand and supply price meet and the market is cleared. Figure 1 illustrates a possible outcome.

The rules for the auction are geared to maximizing the revenue. They require that the buyer pays his stated demand price. This implies a system of price discrimination and capture of part of the buyer's rent. Revenues and unsold allowances are returned on a pro rata basis to those units from which EPA withheld allowances to create the special reserve.

Direct sales differ from auctions in that a given maximum number of permits per year is available at a fixed price of \$ 1500 (per ton SO_2 emissions), indexed to inflation. Allowances are sold to everyone who presents himself as a buyer on a first-come first-serve basis. However, there is a guarantee for an IPP that is planning a new plant and has not been able to obtain allowances at the auction or in the secondary market for a price not higher

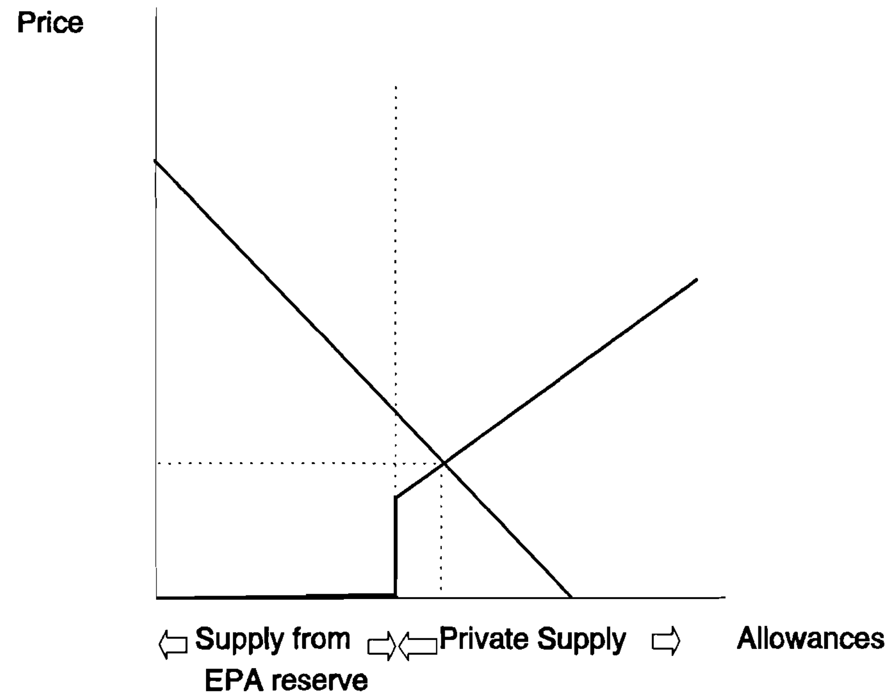

Figure 1 Auction

than \$ 750 that he can buy the allowances he needs for the fixed price of \$ 1500. The price has been set as high as \$ 1500 in order to keep this as a last resort (Zapfel, 1994). Figure 2 shows how direct sales work in principle. Proceeds from the sales are again returned to those units which contributed to the special reserve (USEPA, 1992a).

EPA records all permit transfers and ensures that a unit does not emit more than the allowances it holds. For this purpose, EPA is to maintain an allowance tracking system. Allowance transfers require the submission of transfer forms to EPA, signed by the representatives of both parties (USEPA, 1992b).

4.2 Cost-effectiveness (or how well the permit market performs)

Obviously, it is too early for a full evaluation of the sulfur trading, since Phase I starts in 1995. It is possible, however, to indicate the expected costs savings, compare expected market activity and prices with realizations, and analyze the circumstances that influenced the market so far. Table 2 shows that the sulfur trading program has the potential to cut costs by 40 to 45 percent over the period 1995-2010 (ICF, 1992; ICF, 1994). Costs

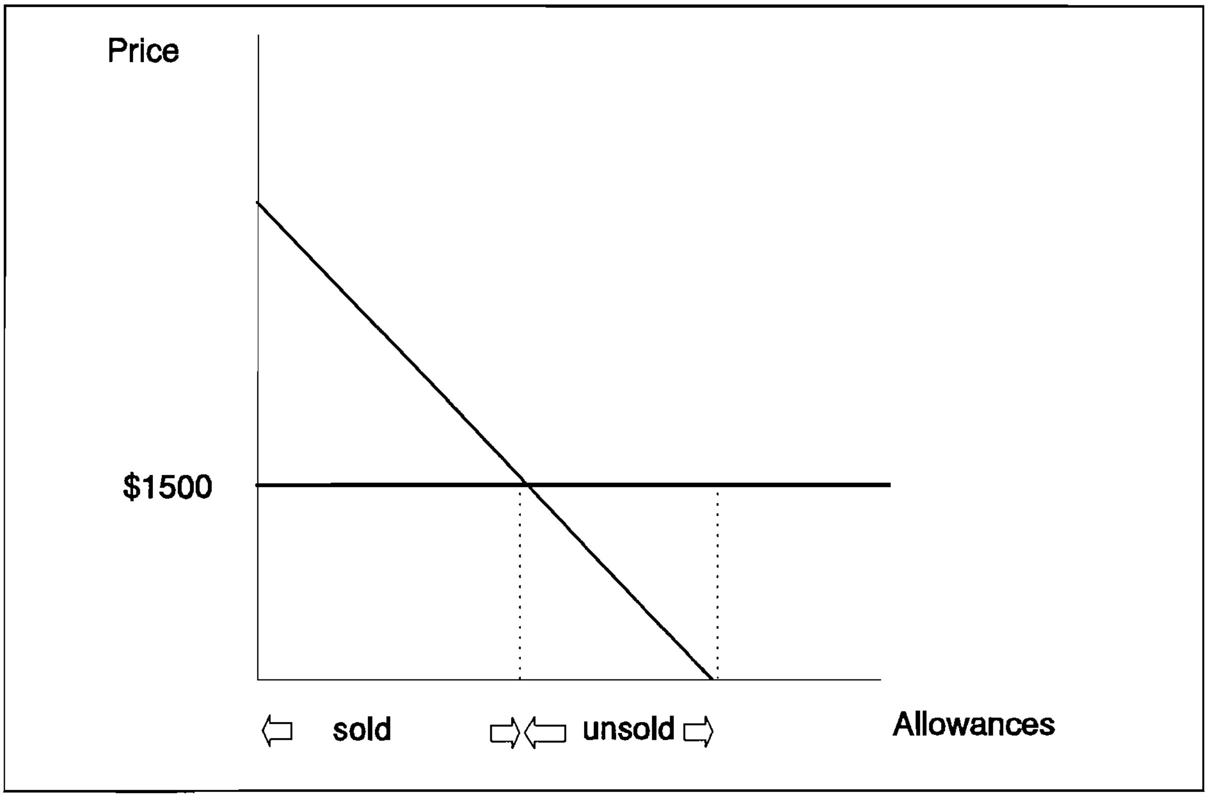

Figure 2 Direct sales

consist mainly of pollution control cost measures and (for a minor part of about 10 percent of total costs) of the costs of implementing the scheme.[3]

The estimates of savings on pollution control costs are based on linear programming models. Implicitly they assume a perfect market. Achievement of the potential cost savings depends on how well the market operates in practice. Figure 3 shows the supply and demand observed at EPA's spot auction in March 1993 for permits to be used in Phase I.

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3 Major component of the allowance system costs are the expected transaction costs of 200 to 400 million US$ for the utilities. Minor cost components are the allowance tracking system, the auctions, direct sales and the conservation and renewable energy reserve. Transaction costs are based on a traded volume of 1 to 2 billion/year and transaction cost of 1.5 percent (ICF, 1992). Major component of the implementation costs, however, are the cost of monitoring (Table 2). Monitoring costs are expected to be lower under the trading program than under a traditional program since EPA does not require continuous monitoring for sources with very low emissions (ICF, 1992, p 4-26). This seems rather artificial since the same rational approach could have been adopted under a traditional program.

Table 2. Estimated costs and cost saving of sulfur trading for the period 1995-2010 (in Million US$ of 1990)

Type of Costs	Traditional Control	National Trading Program	Cost Savings
1. Pollution control	19,100-30,900	9,500-17,100	9,600-13,800
2. Implementation:			
a. Allowance system	0	207-410	-207 to -410
b. Monitoring	2,225	2,612	-387
c. Permits	0	58	-58
Total costs	21,300-33,100	12,400-20,300	8,900-12,900

Source: ICF, 1991

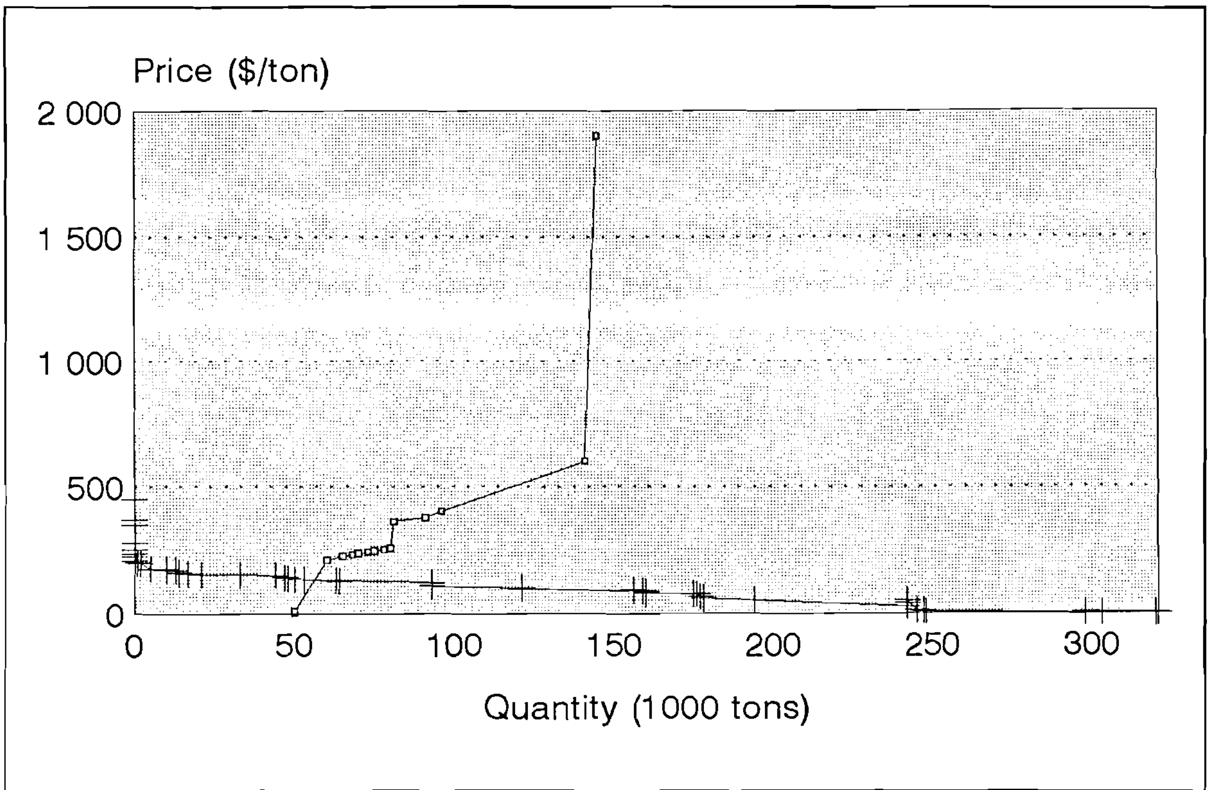

Figure 3 The 1993 spot market auction

Table 3 gives the estimates on prices and volumes based on model calculations (column 2), an overview of actual prices and volumes on the secondary markets (column 3) and the official data on the EPA allowance auction held in March 1993 and March 1994 (columns 4 and 5). The table suggests the following:

Table 3. Market prices and traded volumes

A. Model: total (primary plus secondary) market[a)]

Spot Market in Year	Price 1993[c)]	Traded Volume[b)] kt per year	Banked Allowances kt per year
1997	n.a.	0	2733
2000	261	1075	-1701
2005	384	781	-1000
2010	504	681	- 521

B. Actual market[b)]

Secondary Market			Auction[e)]			
Spot market 1995, phase I in year	Price in $	Traded volume kt/year 1992-May 1994	Spot market in year	Price in $	Traded volume kt	EPA supply
	180-270		1993	131	50	50
	av. 225		1994	150	50	50
Forward market 2000, phase II		2100[d)]	Forward market 2000, phase II			
			1993	122	100	100
	160-250		1994	140	25.4	0
	av. 205		2001, phase II			
			1994	140	100	100

a) ICF (1994)

b) *Wall Street Journal*, August 24, 1993. Anonymous (1993). Lipskey (1993). All prices are expressed in 1993 $.
Revised secondary market trade (based on table 4, Rico, 1995)

$$\frac{2.4 \text{ million}}{2.3 \text{ years}} = 1000 \times 1000 \text{ per year (instead of } (160-120) \times 100) \quad \pm 900$$

part of 2.3 mln trade consists of buying and reselling by 'intermediaries'. 'Net trade' then is 2.03 mln.

c) interstate only

d) total around 2100 of which 420 interstate

e) USEPA (1994).

(1) Prices and trade volumes of the auctions (spot and forward) are far below prices and trade volumes on the secondary market.

(2) Actual prices on the spot market tend to be equal to the actual prices on the forward market.

(3) Actual trade volume (of auction plus secondary market) is higher than the trade volume estimated with the model.

A first question is why prices and quantities on auctions are so much below the level of the secondary market. A number of explanations is given for this phenomenon.

Some authors expect that the pay-as-you-bid format of the auction is an incentive for buyers to state a lower demand price than their true willingness to pay, which would depress the market clearing price and the volume traded (Rico, 1995; Cason, 1993). However, one should bear in mind that the outcome depends on the bid strategy of the buyers at the margin. To avoid the risk of not getting the allowances they have to state a price which is not below the expected market clearing price. Therefore, it is by no means certain that the pay-as-you-bid scheme tends to depress the auction price.

Two other arguments to explain a too low auction price and trade volume seem more relevant. Some brokers believe that EPA's auction is not appropriate for the type of market, since the most significant demand for permits occurs when a utility has to decide to install a scrubber or not. This is easier handled in a few large trades ahead of the compliance dates (Weissman, 1993). In addition, the timing of the first March 1993 auction was not optimal since most companies had just finished their phase I planning and were just starting Phase II. In short, prices and sales at the March '93 auction were depressed, due to the timing of the auction and the structure of the market. The downward bias in market prices might limit the ability of the auction to set cost-effective price signals. It should be noted, however, that in the second auction of March 1994, the market clearing auction prices (on spot and forward market) were about 15 percent above the March 1993 auction price and approached the price in the secondary market. Given the opportunities for profitable arbitrage between primary and secondary markets in 1993 and 1994 we expect the 1995 auction price to be higher and closer to the lowest prices on the secondary market.

A second striking feature in table 3 is that actual prices on the spot and forward market tend to be equal, with forward prices somewhat below the level of spot prices. This may look surprising at first, given the necessity of higher emission reduction in phase II, combined with higher electricity demand and higher fuel input, which induce higher marginal control cost, but actually the tendency to equalization of prices shows that the market works as it should. What happens is that firms bank part of their allowances and professional investors (ICF, 1992, 1994), buy allowances in the 1995 spot market and possibly store them for use or selling in 2000 or later, when emission targets will be more stringent, and marginal abatement cost and (spot) prices of allowances will be higher.[4] The possibility of intertemporal trade means that future scarcity is already signalled in today's price and reduces present use of the commodity. Consequently, emissions in the period 1995-2000 will be reduced below the 1995 target level whereas, from 2000 on, emissions will be somewhat above the target level. The official prognoses have been late in recognizing this impact of the market on the line path of emissions, as Table 4 shows. EPA 90 and RIA 1992 predict a line path of emission reduction according to the legal requirements. This changed in EPA 1993; in ICF 1994 Figure 4 was published and clearly shows the difference between legally required and expected emission reductions.

Table 4. Comparison with 1990 EPA Study and 1992 Regulatory Impact Analysis

Utility SO_2 emission reductions relative to 1980 levels (mmtons)	1995/1997*)	2000	2010
EPA 90 (Senate Bill)	3.4-4.0	6.0-7.1	8.6-8.7
RIA 92	2.8-4.2	5.7	8.4-8.5
EPA 93	5.2	6.2	8.0

*) The RIA and the 1990 study analyzed the year 1995, the current analysis (EPA 93) analyzed the year 1997.

Source: ICF 1994

In a market with perfect foresight and certainty the forward and spot price will coincide. Actually the forward price is 7 to 12 percent lower than the spot price (in both the auction and in the secondary market). The explanation for this phenomenon is that in a world with imperfect foresight, buying phase I allowances in the spot market gives the added option of

[4] Indication of activity of professional investors is the bid in the spot auction in 1994 of the Allowance Holding Corporation which acquired 26% of the 50,000 allowances sold (USEPA, 1994).

using them in the period 1995-2000, as well as the possibility of storing them for use in phase II. The price margin of 10 percent is the premium you pay for the extra liquidity.

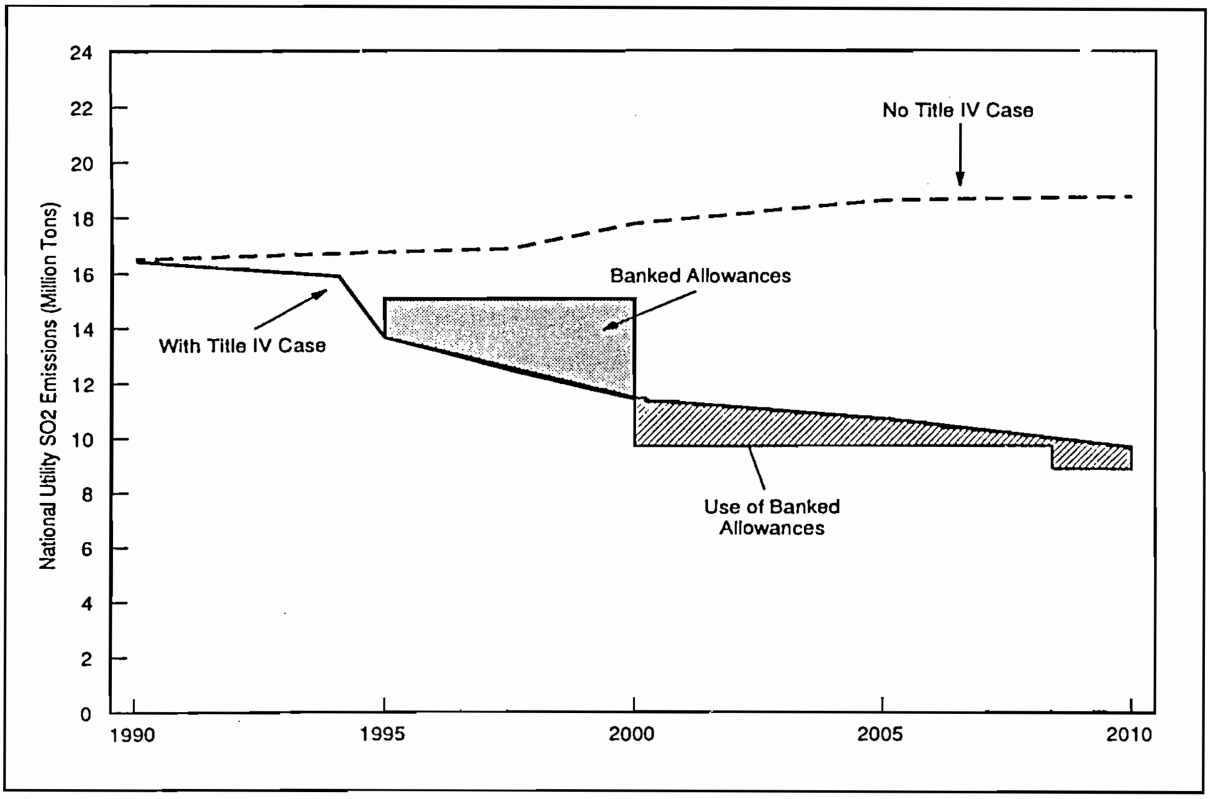

Figure 4 Development of emission levels Source: ICF, 1994

The model predicts increasing real spot prices for allowances, close to a doubling of the price in the decade 2000 to 2010. This reduces the price increase to 7 percent per year on average. In the period 2000-2005, the increase will be about 9 percent and from 2005-2010 about 6 percent. Extrapolating back to 1994 gives us a spot price of 180 US$ (at 7 percent discounting) or 140 US$ (at 10 percent discounting), which is in the range of actual spot prices in 1994. Whether the market really applies a real discount rate of 7 percent is not clear; for example, the (implicit) expectation can be that future marginal cost and spot prices will be below the model estimate; in that case the rate of discount will be lower and vice versa.

A third striking feature in Table 2 is that actual interstate trade on the primary plus secondary market has been above the model estimate up to now. In the model, the volume of interstate trade is between 1100 and 800 kton per year in the period 2000-2010. Actually, interstate trade over the period 1992-October 1994 was about 1500 kton. This might be interpreted as an indication that the allowance market works in reallocating emissions between producers. This is contrary to the rather pessimistic expectations of a number of observers, who have stressed the factors that reduce demand and supply in a way detrimental to environmental effectiveness and cost effectiveness of the program: reduction in capacity use of boilers in phase I, uncertainty about property rights and the regulated character of the electricity industry. These points will be discussed subsequently.

One factor that might have depressed permit demand, at least for Phase I permits, is the existence of a loophole in the legislation. Many utilities have plants that fall under the phase I cap but they also have other plants that do not yet fall under the Phase I cap, but only under the phase II cap. This gives utilities an incentive to run these Phase II boilers at higher generation rates, reducing the electricity output and emissions produced by Phase I boilers and reducing the demand for allowances. EPA is currently implementing regulations to prevent such shifts (Rico, 1995).

A minor element that might have led to a thin market is the uncertainty on the status of property rights. The Clean Air Act makes it clear that an allowance is not an inalienable property right and hence could be limited, revoked or otherwise modified in the future, without compensation. Changes in federal and air pollution regulations could also occur. The EPA, for example, is considering the introduction of a short term standard for SO_2 to avoid health problems. This could lead to limitations on trades. Furthermore, a major topic is whether the technical emission standards have to be applied to new or modified sources or not. Some state that the application of BACT or NSPS in PSD areas is a case-by-case decision of the individual state. Others are of opinion that compliance with standards cannot be avoided (Endres and Schwarze, 1993).

The negative public attitude in some cases and a law suit by New York State in its effort to prevent utilities from selling permits may also have depressed market activity (Malec, 1993; Weissman, 1993). EPA, however, believes that the NY law suit did not have much effect on trading, although some utilities in NY state are "nervous" and are waiting (McLean, 1993).

Another factor influencing a proper functioning of the permit market is the tendency in some states - Bohi (1993) counted 6 - to promote options other than buying allowances, mainly by granting favorable cost recovery of capital cost of scrubbers. This, in itself, could encourage overinvestment in pollution control and selling or banking of allowances. A potential market failure of a more general character is the regulated character of the electric utility industry. Most US electric utilities have monopolies provided by state or local authorities (ICF, 1992). Utility rates and revenues are subject to state or federal control and regulations. Rates for privately owned utilities are set to allow them to recover all "prudently incurred" costs and make limited profits (ICF, 1992). This implies that the utilities' rate of return (profit π divided by the asset or capital base K) has to be below a certain allowed rate of return. If the rate of return allowed exceeds the cost of capital, this will lead the profit maximizing firm to substitute capital for other factor inputs and operate at an output level where cost are not minimized (Averch and Johnson, 1962). In empirical studies, evidence has been found that overinvestments actually may occur. This type of behavior has consequences for the utilities' reactions on a permit market. Decisive is how the initially grandfathered allowances are valued and how revenue from allowances that have been sold (and expenditure on permits that are bought) are treated. Public Utility Commissions (PUC) in most States use the 'original cost method' (Bohi et al., 1990; Endres & Schwarze, 1993). Strict application of this rule implies that allowances that have been grandfathered have a book value of zero, whereas abatement capital will be valued according to investment expenditure. Consequently, abatement capital will enter the rate base and initially grandfathered allowances not. As far as revenue is concerned, the 'Uniform System of Accounts' of the Federal Energy Regulatory Commission (FERC) prescribes that net revenue from selling capital assets has to be transferred to electricity consumers (the rate payers). Tschirhart (1984) has shown that this set of rules leads to a bias in favour of capital-intensive pollution control equipment such as flue gas scrubbers, compared to emission permits. (By the same token utilities have an incentive to overinvest in abatement capital relative to reducing emission by substituting low sulfur coal for higher sulfur coal.) The result of both rules is that regulated utilities overinvest in scrubbers, that prices of emission permits are depressed and that unregulated private electricity producers will underinvest in abatement capital. This distortion in the allocation of abatement capital reduces the cost effectiveness of the trading scheme. To avoid any bias in favour of scrubbers, it would be required that the initial allocation of emission permits and the costs of purchased allowances show up in the rate base (K) and are treated in the same way as investments in flue gas desulfurization equipment (Bohi et al., 1990).

Although there is the critical possibility of overinvestment, it is by no means clear how important the Averch-Johnson effect is, in general, and even more, whether and to what extent it has induced overinvestment in scrubbers in regulated utilities and has depressed prices and trade volume on the permit market. In a summary of regulatory policy and utility compliance plans for 11 states (85 percent of Phase I permits), Bohi (1993) observes that two-thirds of the utilities switch to low sulfur fuels, one-sixth installs scrubbers, and only one-third holds allowances, but such figures in themselves do not say anything about the allocative efficiency of the decisions. End 1993, the most important issue was the uncertainty about what the calculation rules were going to be. Many utilities showed concern over buying and selling permits without knowing how their costs and revenues would be treated by Public Utility Commissions (PUC) (Rico, 1995). This inhibited trades since the PUC's are waiting for the utilities to trade, whereas the utilities waited for the PUC's to formulate the rules for treating costs (Weissman, 1993). Although the majority of PUC's were not contemplating the limitation of the activities of utilities in an allowance trading market, most of the commissions had not yet decided how to treat costs and revenues of trades for ratemaking purposes (Solomon and Rose, 1992). Uncertainty, in particular about the treatment of permits, might well induce utilities to install pollution control capacity and to hoard allowances for later use rather than selling them. This tendency is strengthened by the utilities' reputed conservatism and risk aversion (Hausker, 1992). As of March 1995, most PUC's have decided what they are going to do, but are providing little incentives to engage in trading. Gains of trades are hardly shared with shareholders and typically passed through to ratepayers in the current period. The costs of acquiring allowances are not placed in the rate base but are treated like fuel costs. That is not to say that uncertainty on the allowance market is not important. It appears, however, to be small compared to the uncertainty related to the regulatory reform in the form of emerging wholesale and retail competition. This uncertainty rather makes utilities hesitant to undertake new capital investments (Burtraw, 1995). This seems to fit with what happens in practice where much fuel switching (to low-sulfur coal and to gas) is taking place and little new pollution control equipment is being built.

Transaction costs in terms of finding a trading partner and approval seem not to be a problem. Although brokerage fees are higher than expected (around 5 percent, *Wall Street Journal*, August 24, 1993) they are much lower than under EPA's emission trading, where ranges were between 5 and 30 percent (Foster and Hahn, 1993; Dwyer, 1992). Administrative approval of trades also does not seem to be a distorting factor.

In summary, there are indications that the market works well. Future tighter emission targets from 2000 onwards are signalled by a rising price on the spot market for emissions and induce extra reduction of emissions in 1995. The main remaining problem seems to be uncertainty about the treatment of permit costs and permit capital for regulated utilities and the possibility that the rules, insofar as they are clear, might induce overinvestment in scrubbers in regulated utilities and underinvestment by independent electricity producers.

4.3 Environmental effectiveness, administrative practicality and innovation

The question is: to what extent does the allowance trading program meets its objective of reducing the adverse impacts of acid deposition? The answer depends on both the levels of emissions reduced and their locations, since some areas in the USA are more sensitive to acid deposition than others.

Regarding the total emission cap for phase I, there is a loophole problem. Utilities can shift electricity production to plants that fall under phase II only and thus, unexpectedly, increase emission of phase II units (USEPA, 1993c). As a result, sulfur dioxide emissions could be 1 million tons higher than the goals of the Clean Air Act. To avoid this EPA now requires reports on the generations and emissions during phase I of Phase II boilers and requires an offset of emission reduction in phase I for these shifts (Rico, 1995).

Regarding ambient air quality standards, the risk of exceeding these is nil. First, these standards are presently only exceeded in 4 out of 3000 regions (Leaf, 1993). Second, the new CAA cuts emissions even much further. Finally, although allowances can be freely bought or sold, their use can be prevented if ambient air quality standards are exceeded (USEPA, 1992b).

Whether the allowance trading results in the expected reduction in acid deposition in sensitive areas is more questionable. At first sight, one would expect an improvement, because the inclusion of emission trading programmed made it politically feasible that instead of the expected cutback of 7 or 8 million tons, a cutback in emissions of 10 million ton could be realized (Goffman, 1993). This large scale reduction, and the fact that sources still have to do what states require to meet ambient standards, suggests that, regardless of where the acid deposition occurs, a large decrease in sulphate deposition can occur (Kete, 1992). Furthermore, model studies suggest that, given the distribution of marginal costs over the sources, the trading would reduce emissions and deposition where they were needed to protect sensitive areas (NAPAP, 1991; Goffman, 1993). The latter, however, can be questioned. Bohi (1993) suggest that, due to the constraints on trading, none of the states plan interstate trading matching the output of the optimization model. The three states that do will take positions (buy/sell) opposite to what was expected. A comparison of the interstate trading observed in Rico (1995) with the simulation of NAPAP (1991) sheds some light on the problem. NAPAP (1991) suggests that 9 states would show noticeable changes in emissions due to interstate trading: Indiana, Pennsylvania, Illinois, Kentucky and Ohio would sell. Texas, Michigan, Florida and Massachusetts would buy. However, Rico (1995) shows that of the 5 states expected to sell, three are net sellers in practice (Pennsylvania, Kentucky and Ohio) while two (Indiana, Illinois) buy permits. Of the four NAPAP buyers, three did not trade at all (Michigan, Florida, Massachusetts) and one (Texas) was seller. Consequently, reductions in deposition might not necessarily occur where they would be most beneficial for the environment. The trading program, however, has also enhanced the environmental effectiveness in a way that was not foreseen by the authorities. The interaction of spot and forward market results in extra reduction in the period 1995-2000 in exchange for higher emissions from 2000 on. This can be valued positively from an environmental point of view, since it slows down the rate of acidification in sensitive areas.

Administrative practicability depends on information requirements and costs. Table 2 shows that implementation, i.e., monitoring costs are relatively modest, about 10 to 20 percent of abatement costs. The larger part of it, in particular the cost of monitoring, would also have to be born under a regulatory regime. The major additional administrative costs are costs of the emission allowance tracking system of $200 to 400 million and the permit costs (Table 2). These costs might be underestimated in view of the additional measures taken to close the loophole, since this leads to additional, cumbersome paperwork of the kind associated with previous trading programs (Rico, 1995).

There is some evidence that the sulfur trading stimulates innovation. The average removal efficiency of flue gas scrubbers has increased and their design has become simpler since backup installations are no longer needed (McLean, 1993; Burtraw, 1993). Moreover, due to increased cross-competition between low-sulfur coal and scrubbers, both scrubber and low-sulfur coal prices dropped and pollution control costs have been lowered (Burtraw, 1993). This is not only the result of decreased scrubber costs, but also due to the increased availability of other options: despatching electricity, more conservation and efficiency management and the supply of low sulfur coal (Weissman, 1993).

5. Conclusions

The acid rain program has established a basis on which a market for emission permits can develop. Compared to the EPA trading program important improvements to harness market forces have been made:

- a clearly defined cap on total emissions;
- baseline emissions have been delineated clearly, reducing largely the uncertainty about property rights (entitlements) that inhibit trade;
- no confiscation of emission allowances if a trade is made;
- no necessity of prior authorization for a trade;
- no restriction of trade to specific areas;
- clear rules for monitoring and enforcement with immediate and severe sanctions for non-compliance.

As a result, there are few formal restrictions to inhibit realization of cost savings through emission trading. Since the number of potential trading partners is large, transaction costs can be low, trades and price notations frequent, thus enhancing the market as means to signal environmental scarcity.

Insofar as there are problems with the new trading program, these mainly arise from rules and interventions of authorities that interfere with the market. A potentially major problem is the restriction of the trading program to one heavily regulated sector: the electricity industry. The incentives within utilities, together with the possible distortion of PUC rules for rate setting may result in not all potential cost savings being actually used.

The second bottleneck of some significance is the intervention of state governments, obliging utilities to buy coal produced in the state and offering subsidies for scrubbers.

As a third point a question may be raised as to whether the EPA did not overorganize the market by setting aside a reserve of emission allowances and organizing auctions. At the same time, the precautions taken by EPA may be understood, given the uncertainty about how utilities under existing regulation would react.

What lessons can Europe learn from the experiences in the USA? The first is that there are no sound economic and environmental reasons for European timidity in taking steps to increase the flexibility of the existing regulation of air pollution. Efforts could and should be made to lay the foundation for regular national markets for SO_2 emission permits. Countries with well developed environmental policies like Denmark, the Netherlands and Germany already largely fulfill the necessary preconditions. These are

- emissions ceilings for important groups of stationary sources set out on a timetable;
- registration (audits) of SO_2 emissions of single units, which can serve as a baseline;
- progress in monitoring and enforcing the existing system of direct regulation.

The 'missing link' in air pollution policies for stationary sources in these European countries is the twofold decision to (1) define permission to emit in terms of a fixed emission quota per firm instead of emission per unit of fuel input or similar standards, (2) make the emission quota tradeable between firms. Once these fundamental decisions have been made these elements have to be fitted into a framework for national emission trading analogous to the US acid rain program. The major material difference to existing environmental regulation would be the abolishment of regulated 'free entry' of new sources (either from existing firms, or entrants).

From the US experience it can also be learned that it is easier to organize a permit market for one homogeneous sector than a market that covers several and heterogeneous sectors. In small countries like the Netherlands and Denmark the number of producers in the electricity sector is so limited and organized like cartels that a regular competitive market will not develop. A solution would be to cover several sectors in one national scheme, or break up the national electricity cartels and form an international permit market for the electricity sector, and possibly other sectors.

In following these lines of actions the differences between Europe and the US should not be forgotten. In Europe, the differentiation in sensitivity of ecosystems for acid deposition is much larger than in the US, especially the difference between (very sensitive) Northern Europe and (slightly sensitive) Southern Europe. An international system of tradeable permits would have to take these environmental constraints into account (for example, by restricting trade to groups of adjacent countries). It also makes a difference that in Europe existing regulations (standards) to reduce acid deposition are more stringent then the position from which the acid rain program in the U.S. was initiated. In the short run, cost savings will, therefore, be lower in Europe than in the US. Politicians would have to take more into account the long-run benefits of having a market with prices that signal environmental scarcity in a world with increasingly tight emission targets, where decisions on pollution control technology become more and more complex and innovation in pollution control technology will be of increasing urgency.

A last, but not the least difference is that states in the U.S. are more homogeneous with regard to their environmental policies than the countries in Europe. In the U.S., delineation of base emission, monitoring and application of sanction do not differ strongly between states. In Europe this is certainly not the case. It can be expected that in countries like Denmark, the Netherlands and Germany the preconditions for a permit market mentioned before are fulfilled. However, it would be absurd to try to introduce tradeable permits in, for example, those southern European countries where environmental policy still is in its stage of inception. Emission targets will be lacking, information on emissions per source or unit is unavailable or unreliable, monitoring is of low quality and enforcement lax. If essential preconditions are not met, any form of environmental policy will largely fail, but emission trading might be even less successful than a policy of direct regulation.

Therefore, a European market for SO_2 allowances will be restricted for a double reason. The first one has to do with environmental constraints; the second one with differences in the quality of environmental policies. The last obstacle can be overcome in the course of time and this might induce speculation about a Europe of 'two speeds' in the area of air pollution policy. The differences in sensitivity of soil for acidification are permanent and prohibit a simple emission trading system for the whole of Europe.

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